



Conceptions of nature of technology in educational research: a systematic literature review

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Abstract

Since the inception of Technology Education, the learning area and its advocates have struggled for legitimacy. Part of this challenge stems from difficulties in articulating the nature of technology (NoT) and its unique contribution to education. This article presents a systematic review of NoT in educational research, analysing empirical studies that investigate teachers' conceptions of NoT. An analysis of the 22 included studies showed significant differences in the ways that NoT is theorised in educational research. In highlighting both the complexity of NoT and Technology Education as a learning area, 11 distinct aspects of NoT were identified in this study. This analysis also revealed tensions between a focus on specific *technology/ies* and *Technology-as-phenomenon*, suggesting the need for conceptual coherence in future research. Implications are drawn for understanding NoT, Technology Education, and the position of Technology Education in broader education narratives.

Keywords Nature of technology (NoT) · Technology education · Conceptions · Systematic literature review

Introduction

The general discourse surrounding *technology* typically evokes notions of high technology, cutting-edge electronic devices such as computers and smartphones (de Vries, 2016). Despite the ubiquity of this view, the Philosophy of Technology field has developed and presented a more comprehensive conception of what constitutes technology, and it is widely accepted that technology goes beyond tangible objects or artifacts, as it has also come to represent forms of knowledge and human activity (de Vries, 2016; Houkes, 2009; Mitcham, 1994; Volti, 2009). Further, technology is continuously evolving, and as it evolves, its impact on and relationship with society is becoming increasingly complex (Arthur, 2009).

As a curriculum learning area within formal education¹ technology has its roots in the vocationally oriented industrial-arts movement of the mid-1900s (Banks & Williams,

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2022; de Vries, 2018b; Lewis, 2004). Despite an initial focus on the preparation of students for the world of work, technology as a field is now presented as an important contributor to general education. The rationales for this are manifold but typically reference the ubiquity of technology in the world today (de Vries, 2018a), and the importance for students to develop a comprehensive understanding of how to engage with, use, develop and consider the implications of technology (Jones & Moreland, 2003; Pleasants et al., 2019). Central to this shifting emphasis has been the emergence of *technological literacy* internationally (Compton & France, 2007; ITEEA, 2020; Nordlöf et al., 2022; Williams, 2017). The notion of technological literacy as an educational objective is widely acknowledged to encompass multifaceted dimensions beyond the production or utilisation of technological artifacts, encompassing social, political, ethical, and environmental considerations (Dakers, 2014a, 2014b), whether presented as a component of science, technology, engineering and mathematics (STEM) education (Bybee, 2013; Hallström & Ankiewicz, 2023; Tang & Williams, 2019) or within Technology Education³ as an independent field of study (Dugger, 2001; Ingerman & Collier-Reed, 2011; Lewis & Gagel, 1992; Williams, 2009). While this article uses technological literacy as a framework to understand the different purposes for teaching technology, it should also be noted the concepts of technological capability (Gibson, 2008; Kelly et al., 1987; Kimbell & Stables, 2007) and technacy (Seemann, 2009) are also widely used in Technology Education rhetoric.

Just as constructs such as technological literacy, technological capability and technacy have been developed as ways of articulating goals for learning in Technology Education, the Philosophy of Technology has also been highlighted as fundamentally important (Burns, 1992; Luckay & Collier-Reed, 2014; Mawson, 2013; Roberts & Kruse, 2022). Central to this evolution has been the identification of students' limited understandings of technology (Burns, 1992; Cajas, 2001; DiGironimo, 2011; Rennie & Jarvis, 1995; Rocha Fernandes et al., 2018) and an uncritical or naive optimism towards technology held by students and technology educators (Pleasants et al., 2024; Waight, 2014). This has manifested with nature of technology (NoT) being included within policy documents as a central construct within technological literacy (ITEEA, 2020; Jones, 1997; Ministry of Education, 2017; Skolverket, 2011). Pleasants et al. (2019) note that studies which investigated students' conceptions of NoT have predominantly focused on how technology is defined, the sort of thing that students categorise as technology, and the relationship between science and technology (Constantinou et al., 2010; Ryan & Aikenhead, 1992). While these aspects are important, they present a limited view of NoT when compared with scholastic endeavour and the emerging broader conceptions of NoT within the Philosophy of Technology field. Pleasants et al. (2019) in turn call for a more extensive and detailed review of the NoT literature.

The present study aims to investigate representations of NoT in educational literature, through analysing studies that investigate teachers' conceptions of NoT. This study is justified by the ongoing debates surrounding students' conceptions of NoT, and the somewhat precarious position the Technology Education holds within broader education narratives (Cullen & Guo, 2020; McGarr & Lynch, 2017). As the intermediaries between international, national, and local policies and the enacted practices, teachers are uniquely situated to offer valuable insight into NoT. Teachers' concepts of technology and Technology Education influence student learning, as research has shown that both teacher knowledge and student learning can be enhanced in technology where there is a deliberate focus on developing teacher and student concepts of NoT (Cowie et al., 2008; Jones et al., 2013). It is envisioned that the findings of this literature review will thus contribute to the development of more effective Technology Education policies that better reflect the multifaceted

dimensions of technology and its relationship to society. First however, a broader investigation of Technology Education as a learning area is undertaken, along with an examination of the prevailing themes and contentions within NoT literature.

Nature of technology: contrasting perspectives and misconceptions

As noted in the introduction, technology is understood in different ways in different contexts, and as a result, the concept is used for different purposes. Several authors have outlined the challenges for Technology Education as a result of these differing perspectives on technology (Dakers, 2018; Pleasants et al., 2019). Primarily, the challenges relate to the different ways in which the general population understands technology, and how reductive conceptions of technology misrepresent the promise, or at the very least, the potential of Technology Education. In a similar vein to lay perspectives on NoT, misconceptions have also been identified in the corpus of educational research literature (Sivaraj et al., 2019). As such perspectives and misconceptions only serve to perpetuate subject hierarchies found in schools today (McGarr & Lynch, 2017), here, they are used as the rationale for exploring how NoT is understood in the corpus of literature.

In many national education contexts, Technology Education has evolved from craft predecessors (Banks & Williams, 2022). The focus within craft education was learning making skills, often associated with a specific profession (e.g., carpentry, metalwork). With the industrial revolution, this craft educational model shifted towards an industrial arts educational model. Much of the student autonomy in designing and deciding what to make was lost, as the classroom, and increasing 'workshop' activities involved all students making the same product. De Vries (2018b) notes that the quality of the product evolved as the main criterion for assessing learner performance in Technology Education. Indeed, research within modern-day Technology Education has continued to outline the dominance of craft-oriented models found in schools to this day (Doyle, Seery, Canty, et al., 2019; Doyle et al., 2024; Buckley, 2023).

With a focus on the development of technical skills specific to a vocation, it is easy to see how technical or craft education is viewed as vocational. De Vries highlighted that the reason this became an issue of Technology Education "is that vocational education in itself is seen as lower status than pre-university or pre-college education" (2018b, p. 75). In essence, this results in the valuing of academic subjects with a predominantly cognitive orientation above those with craft components. It should be noted here that the technical predecessor to technological education² was inherently vocational in some contexts. Whereas technical education mirrored the apprenticeship model of the medieval guild, where a master craftsman facilitated the development of specific skills associated with a vocation context, in the 1980s it became apparent that such a model no longer reflected the technologically mediated world we now inhabit (Dakers, 2005a). With this, an alternative model of technology, and in turn Technology Education was conceptualised. In outlining how Technology Education can contribute to all members of society, the curriculum, and its advocates have attempted to traverse to general education (Jones, 2009).

De Vries (2018b) also noted that the close relationship between Technology Education and other learning areas has stymied the development of the learning area. Science education, and in particular the Science and Technology Studies (STS) education movement was pivotal in introducing the concept of technology to formal education. Despite the apparent advantage of situating technology as a component of STS education, the manifestation of technology presented was cause for concern. The rationale for STS was a critical

analysis of the negative impacts of science on societies, where technology was presented as the application of science. De Vries notes that this was the perception in the ‘technology as applied science’ paradigm, which at that time was still in “the mainstream of thinking about the science-technology relationship, both in philosophy and in education” (2018b, p. 76). In the 40 or so years since the inception of STS education, the relationship between science and technology has been investigated in detail. It is now widely accepted that technology is much more than applied science. For example, Arthur (2009) outlines the relationship between science and technology as symbiotic, technology is developed from harnessing the phenomena discovered through the scientific process, but equally, science is developed with technology, as the instruments, methods and experiments used in scientific endeavours are technological in nature. Despite such significant shifts in understanding of NoT, the place of Technology Education in the curriculum today remains somewhat precarious (McGarr & Lynch, 2017), and similar to the tensions between Technology Education and STS as a context, the place of Technology Education relative to STEM education narratives is widely contested in literature today (Bell, 2016; Keirl, 2015, 2018; Williams, 2011b).

The present study

Technology as a concept is difficult to define. The challenges and misconceptions outlined previously are in part illustrative of how NoT is represented in the Philosophy of Technology field. In breaking with the past, policy documents are invariably apprehensive in articulating declarative content knowledge, instead of broad processes and methods, as well as how knowledge is treated within technological activity is put to the fore (de Vries, 2016; Houkes, 2009; Norström, 2013). In the absence of defined curricular boundaries, which were facilitated in technical education, broad conceptual terms such as technological literacy have come to the fore as the rationale for teaching technology. It is perhaps unsurprising then that different contexts for Technology Education can have vastly different manifestations within policy documents (Banks & Williams, 2022). It should be emphasised that this is not viewed as a weakness within the Technology Education field, but a strength, as it is acknowledged that the technology educator has significant autonomy in comparison to other learning areas in deciding what and how to teach (Doyle, Seery, Gumaelius, et al., 2019; Rohaan et al., 2010; Spendlove, 2012). Despite the apparent benefits of a more reflexive approach to Technology Education, the tenuous place held in the curriculum in tandem with the different rationales for teaching technology identified in the research (Reinsfield & Williams, 2017), suggests the need for a more comprehensive exploration of NoT. Recently this area has seen some focus from the theoretical perspective, most notably the work of Pleasants et al. (2019) in proposing NoT issues for consideration in a STEM context. In addition, NoT is increasingly the focus of empirical investigations (Blom & Abrie, 2021; DiGironimo, 2011; Liou, 2015). The research presented herein set out develop our understanding of the NoT in education research, through investigating empirical representations of the construct. To guide this review, the following research question was developed:

(1) How is the nature of technology theorised in empirical investigations of the construct?

Research methodology

This systematic literature review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Moher et al., 2015; Page et al., 2021). A systematic approach, following the guidelines presented by Alexander (2020) was selected to ensure that selected studies are representative of the literature.

Conducting the literature search

Piloting the search protocol

Given the complexity of NoT as a construct, and the different terms used to explore it in educational research, this study was piloted, and search criteria were revised to include a more expansive literature basis. Referential backtracking from the initial analysis identified studies that used variations of terminology to investigate NoT. For example, Jarvis and Rennie (1996) use the phrase “understanding of technology” which was not identified in the database search during the pilot study. As a result, more expansive search terms and elaborate syntax were developed to broaden the body of literature identified. This elaboration was justified as the change facilitated a more extensive review of NoT construct. The revised selection criteria are defined in Table 1.

Search strategy

As noted, this review followed the PRISMA guidelines for conducting systematic reviews (Liberati et al., 2009; Page et al., 2021). Search terms were designed and refined through the exploration of studies and the pilot carried out in January 2023. The search terms used in this review focused on three concepts: the construct under investigation (technology and NoT), how the authors reported on the construct (broadly, knowledge, beliefs, or attitudes), and the participants in the study (teachers, at any career stage, including pre-service teachers). See Table 2 for the specific search terms and syntax deployed in each database. A search period was not defined for this study as no systematic review was found to investigate teachers’ conceptions of NoT previously. The final search was conducted on the 4th of March 2023. The search yielded a total of 991 records from the following databases

Table 1 Inclusion and exclusion criteria for this review

Inclusion criteria	Exclusion criteria
Explicit focus on investigating teachers’ understanding of technology in a holistic sense (i.e., NoT)	Focus on educational technology (as one manifestation of technology), or specific components of technology (for example ‘design’) were not included
Based on empirical evidence	Theoretical and discussion papers
Focused on teachers or pre-service teachers of formal education settings	Non-formal education settings such as summer camps and after-school programs were not included
Peer-reviewed	Non-peer-reviewed
Journal article	Theses, conference publications, books, book chapters and reports (incl. grey literature)
Written in the English language	–

Table 2 Search syntaxes for individual databases

Database	Search syntax	Database filters	Records returned
Scopus	<p> "Perceptions about technology" OR "Perceptions of technology" OR "Views about technology" OR "Views on technology" OR "Understanding about technology" OR "Understanding of technology" OR "Conception about technology" OR "Conception of technology" OR "Beliefs about technology" OR "Beliefs of technology" OR "Perspectives about technology" OR "Perspectives of technology" OR "nature of technology" AND knowledge OR conception* OR perception* OR belief* OR view* OR opinion* OR attitude* AND teacher* OR pre-service AND teach* OR preservice AND teach* OR "PST" OR "initial teacher education" OR "ITE" </p>	<p> <i>Search:</i> Article title, Abstract and Keywords <i>Language:</i> English <i>Source type:</i> Journal </p>	n = 230
ProQuest Education	<p> notfi("Perceptions about technology" OR "Perceptions of technology" OR "Views about technology" OR "Views on technology" OR "Understanding about technology" OR "Understanding of technology" OR "Conception about technology" OR "Conception of technology" OR "Beliefs about technology" OR "Beliefs of technology" OR "Perspectives about technology" OR "Perspectives of technology" OR "nature of technology") AND notfi(knowledge OR conception* OR perception* OR belief* OR view* OR opinion* OR attitude*) AND notfi(teacher* OR pre-service AND teach* OR preservice AND teach* OR "PST" OR "initial teacher education" OR "ITE") </p>	<p> <i>Limit to:</i> Peer reviewed <i>Source type:</i> Scholarly Journals <i>Document type:</i> Article <i>Language:</i> English </p>	n = 113

Table 2 (continued)

Database	Search syntax	Database filters	Records returned
Academic Search Complete, ERC and ERIC via EBSCOhost	<p>AB ("Perceptions about technology" OR "Perceptions of technology" OR "Views about technology" OR "Views on technology" OR "Understanding about technology" OR "Understanding of technology" OR "Conception about technology" OR "Conception of technology" OR "Beliefs about technology" OR "Beliefs of technology" OR "Perspectives about technology" OR "Perspectives of technology" OR "nature of technology")</p> <p>AND</p> <p>AB (knowledge OR conception* OR perception* OR belief* OR view* OR opinion* OR attitude*)</p> <p>AND</p> <p>AB (teacher* OR pre-service AND teach* OR preservice AND teach* OR "PST" OR "initial teacher education" OR "TTE")</p>	<p><i>Limit to:</i> Peer reviewed</p> <p><i>Search mode:</i> Boolean/Phrase</p> <p><i>Publication Type:</i> Academic Journal</p> <p><i>Document Type:</i> Article</p> <p><i>Language:</i> English</p>	n = 348
Google Scholar (advanced search)	<p>Find articles:</p> <p>with all of the words: technology, education, teacher</p> <p>with the exact phrase: "nature of technology"</p> <p>with at least one of the words: knowledge, conception, perception, belief, view, opinion, or attitude</p>	<p><i>Limit to:</i> anywhere in the article</p>	<p>Returned 14,600 articles</p> <p>n = 300</p>

and searches: Academic Search Complete, ERC and ERIC via EBSCOhost (348 records), Scopus (230 records), Education database via ProQuest (113 records) and Google Scholar (14,600 records were returned; as per Haddaway et al. (2015), the first 300 records were extracted). In addition, where the database incorporated filters, they were used in accordance with the inclusion and exclusion criteria presented previously.

Screening

Following the initial database search, records were loaded into a reference management software program to identify duplicates. A total of 286 duplicate records were identified by the reference management software and subsequently removed following a manual review. This yielded a total of 705 records of which the title and abstracts were screened according to the inclusion and exclusion criteria (see Fig. 1 for PRISMA flow diagram). The screening process was carried out in two phases. First, the records were screened by reviewing titles and abstracts. Records were excluded at this stage if it was clear that the

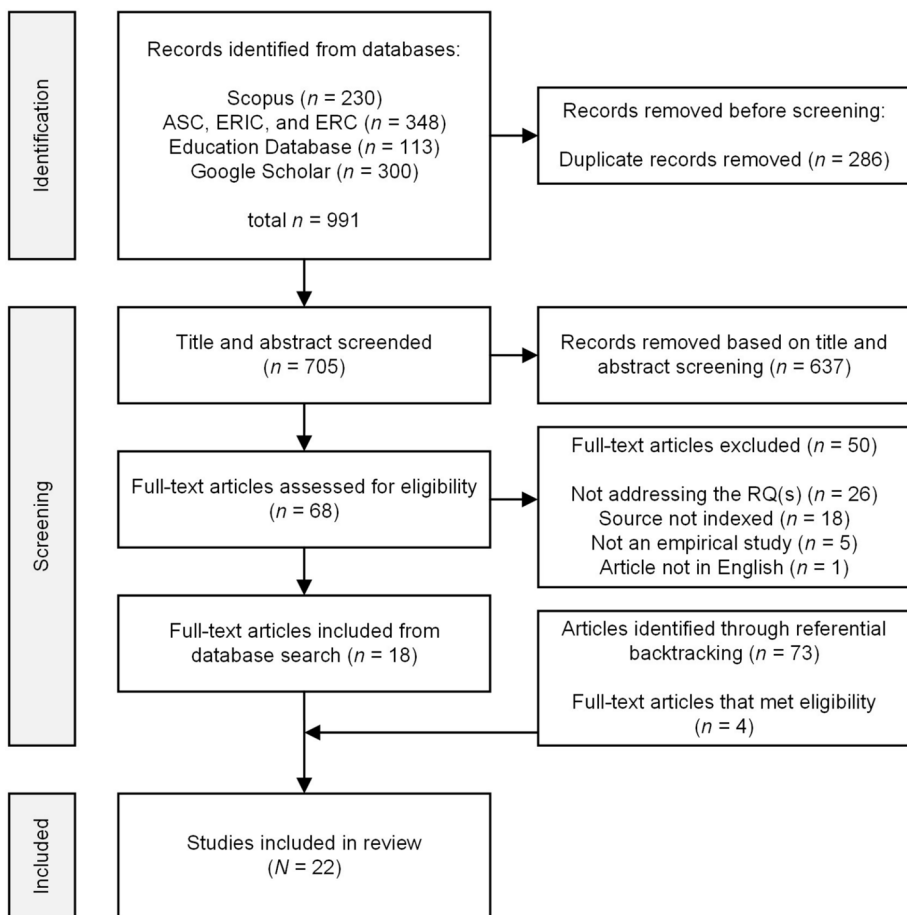


Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram of the screening process, showing how publications for inclusion were refined through the screening process

title or abstract met exclusion criteria or contradicted inclusion criteria. If a title provided sufficient information for exclusion, then the abstract of that article was not read.

The full-text review shifted the emphasis to considering whether the article under consideration met all inclusion criteria. The articles were assessed based on their capability to meet inclusion criteria and address the research question. In addition to the quality components of the inclusion criteria (Wilson & Anagnostopoulos, 2021), if the journal in which the records were published were not recognised by Clarivate's Social Science Citation Index (SSCI) or if a SCImago Journal Rank (SJR) has not been provided, then these records were excluded ($n=12$). As shown in Fig. 1, a total of 50 articles were excluded during the full-text review.

Referential backtracking

The final stage of literature identification involved the process of referential backtracking (Alexander, 2020). In acknowledging the limitations of search engine algorithms and the potential for tangential terms to those specified in search criteria to be missed in the literature search, referential backtracking focuses on the bibliographic information of the records included in the review. As such, the reference lists of all articles that progressed from full-text review ($n=18$) were assessed to identify additional literature that was not identified in the initial search. 73 records were identified from an analysis of these reference lists, after duplicates were removed ($n=37$), 36 records were assessed following the protocol outlined above. As a result of the referential backtracking, an additional four articles were added to the corpus of literature for review. Thus, the resulting $N=22$ articles were included in this systematic review.

Data analysis

During the literature search, once the preliminary screening of titles and abstracts had been completed, general information on each article was recorded on a spreadsheet. The appraisal of full-text articles developed these criteria, by also considering the research context, methodological approach, sample size and the participants in the study. A consolidated version of this preliminary analysis is presented in Table 3. Following this descriptive analysis of the literature included in this review, an inductive thematic analysis (Braun & Clarke, 2006, 2022) was carried out to determine the theorisation and any findings associated with NoT presented in the identified literature. This analysis was influenced by the nature of the research included in the investigation, as not all studies adopted a deductive approach to investigating NoT. Thus, this analysis focused on the theoretical frameworks of articles that designed an instrument to analyse teachers' conceptions of NoT. After the theorisation of NoT had been analysed, attention turned to the findings related to teachers' conceptions of NoT reported in the studies.

Throughout this analysis, differences in the level of abstraction at which technology was discussed was identified. As will be presented in the findings, Keirl's (2015) distinction between *Technology* (big T) and *technology/ies* (small t) to delineate Technology-as-phenomenon and specific identifiable technologies was adopted. At this stage of the analysis, the discrete components of technology identified in the literature were coded axially, with a specific focus on the level of abstraction of technology under consideration.

Table 3 Aspects of the nature of technology theorised by authors in the corpus of literature

Author(s) (Year)	Explicit framework not pre- sented	Technol- ogy as artifact	Technol- ogy as human activity	Technology as progression	Technology as knowl- edge	Rela- tionship between technology and science	Technol- ogy as system	Technology and society and Ethics	History of technology	Definition of technol- ogy
Bungum (2006)	X									
Chen (2011)			Im							Im
Chikasanda et al. (2011)	X									
Davies and Rogers (2000)	X									
Fleming (1992)		Ex	Ex		Ex		Ex	Ex		
Gök and Erdoğan (2010)	X									
Jarvis and Rennie (1996)	X									
Jones and Carr (1992)	X									
Kärkkäinen and Keinonen (2010)		Ex	Ex	Ex			Ex	Ex	Ex	Ex

Table 3 (continued)

Author(s) (Year)	Explicit framework not pre- sented	Technol- ogy as artifact	Technology as human activity	Technol- ogy as volution	Technology as progres- sion	Technology as knowl- edge	Rela- tionship between technology and science	Technol- ogy as system	Technology and society Ethics	History of technology	Definition of technol- ogy
Kim and Song (2021)		Ex	Ex		Ex	Ex		Ex		Ex	
Koc (2013)	X										
Lee et al. (2020)	X										
McRob- bie et al. (2000)		Ex	Ex					Im		Ex	
Mittell and Penny (1997)	X										
Rennie (1987)	X						Im				
Rowell et al. (1999)		Ex	Ex	Im		Ex	Ex				
Sade and Coll (2003)	X										
Stein et al. (2007)	X										
Symington (1987)	X	Im									

Table 3 (continued)

Author(s) (Year)	Explicit framework not pre- sented	Technol- ogy as artifact	Technol- ogy as human activity	Technol- ogy as volition	Technol- ogy as progress- ion	Technol- ogy as knowl- edge	Rela- tionship between technology and science	Technol- ogy as system	Technol- ogy and society	Techno- logical Ethics	History of technology	Definition of technol- ogy
Waight (2014)					Ex	Im		Ex	Ex			
Xu et al. (2022)	Ex	Ex	Ex			Ex	Ex	Ex	Ex	Ex	Ex	
Yenilmez Turkoglu et al. (2022)							Im	Ex	Ex			Ex

Ex explicit inclusion as an aspect of NoT, Im implicit inclusion as related to NoT, X no explicit theorisation of NoT presented

Findings

While an extensive overview of the contexts and methodological approaches adopted in the studies is presented in Appendix 1, it is important to draw the reader's attention to significant findings. The studies were from Australia ($n=4$), Turkey ($n=3$), England ($n=3$), Canada ($n=2$), New Zealand ($n=2$), and, the United States of America ($n=2$), the remainder having been conducted in China ($n=1$), Finland ($n=1$), Malawi ($n=1$), Norway ($n=1$), the Republic of Korea ($n=1$), and, Solomon Island ($n=1$). A wide variety of methodological approaches were used, with eleven studies employing a qualitative design, two using a quantitative design, and nine employing a mixed-methods approach. Where the participant's school type was published, nine included participants from early childhood/primary schools only, nine included post-primary/secondary schools only, and four included participants across all levels of formal education (kindergarten to year 12 students [K-12]). Six of the studies investigated pre-service teachers (PSTs: authors also use the term Initial Teacher Education [ITE]), and the remaining sixteen involved practicing teachers. Regarding the curricular specialism of the participants in the studies, it was identified that a minority of studies explicitly investigated technical/Technology Education (pre-service) teachers ($n=4$). In comparison, the remaining eighteen studies did not explicitly focus on Technology Education but rather included teachers who were either generalists ($n=11$) or teachers of science ($n=6$) or mathematics ($n=1$). The sample size of the studies ranged from four participants (Stein et al., 2007), to a survey of 906 ITE students in the New Zealand context (Lee et al., 2020).

While this review's specific focus is how teachers' conceptions of NoT are investigated in educational research, throughout the pilot study, similar studies were identified that aligned but used slightly different terminology. For example, within this study conception of (Waight, 2014; Xu et al., 2022), perceptions of (Bungum, 2006; Jones & Carr, 1992; Kärkkäinen & Keinonen, 2010; Kim & Song, 2021; Lee et al., 2020; McRobbie et al., 2000; Rennie, 1987; Rowell et al., 1999; Yenilmez Turkoglu et al., 2022), perceptions about (Chen, 2011; Gök & Erdoğan, 2010; Jarvis & Rennie, 1996), views towards (Chikasanda et al., 2011), views of (Fleming, 1992; Sade & Coll, 2003) conceptions about (Koc, 2013), understanding of (Xu et al., 2022), thinking about (McRobbie et al., 2000), and, perspectives of (Yenilmez Turkoglu et al., 2022) technology were all used at various stages to report on teachers' conceptions of NoT. The intention here is not to provide an exhaustive list of the different terminology but rather to point to the variety of terms used, often within the same study.

Theorising the nature of technology

Of the 22 empirical studies included in this review, nine presented an explicit theorisation of NoT. Eight of these studies presented a theoretical framework that synthesised existing literature concerning NoT in educational research (DiGironimo, 2011; Rocha Fernandes et al., 2018; Waight & Abd-El-Khalick, 2012) and/or work from the Philosophy of Technology field (Arthur, 2009; de Vries, 2016; Kline, 1985; Mitcham, 1994; Volti, 2009). Chen (2011) on the other hand, presented a dichotomous theoretical framework for NoT. Despite being situated in an educational technology context, Chen criticised the limitations of an instrumentalist view of technology, stating that such a view can be traced back to the "legacy of Aristotle, who posits that technological products have no meanings in themselves and that technology receives its justification from serving human life" (p. 57).

In direct contrast to the instrumental theory lies the work of Heidegger (1977) and Ellul (1964), who advocate a substantive theory of technology. Substantive theorists posit that technology is “not external to human existence; rather, it is intertwined with the existential structure of human beings” (Chen, 2011, p. 58). As a result of this, substantive theorists view technology, humans and society as dialectically intertwined, now instrumental to our way of life. Across the nine studies that theorised NoT, 37 discrete components of NoT were identified. Following a thematic analysis of these components and the descriptions of the components presented in the studies, they were synthesised into eleven distinct components of NoT (Table 3).

Technology as artifact

Xu et al. (2022) noted that when we talk about technology, most people first think about modern technological artifacts such as computers, televisions, machines, and cars. These technologies were referred to as “object” (Xu et al., 2022, p. 2616), “artifact” (Kim & Song, 2021, p. 4) and “hardware” (Fleming, 1992, p. 142). Despite the different terms used, these technologies are represented as identifiable and specific technologies. The association between technology and Information and Communication Technology (ICT) was noted by several scholars. This is perhaps most pertinent to Fleming’s use of hardware to denote physical technologies, as the everyday use of the term tends to be inextricably linked with ICT. Fleming (1992) cites their earlier work (Aikenhead et al., 1987; Fleming, 1989) while exploring tensions between ICT and Technology, and in building upon the work of Kline (1985), it is noted that the use of hardware does not traditionally have the ICT connotations it is associated with today. Instead, the traditional, more common usage was to denote a manufactured article, “things made by humans that do not occur naturally on earth” (Kline, 1985, p. 215). Kim and Song (2021), in building upon their synthesis of previous investigations into NoT (DiGironimo, 2011; Liou, 2015; Waight, 2014; Waight & Abd-El-Khalick, 2012), highlight that technology as artifact includes the vast array of artifacts created by the human species, ranging from Palaeolithic stone implements to state-of-the-art computers.

Technology as human activity

The process of developing specific technologies was characterised as an important aspect of NoT by Fleming (1992), describing technology as “the process of manufacturing hardware” (p. 142). Similarly, Kim and Song (2021) presented “technology as human practice” (p. 4) in their study, and developing upon this later in the article, describe technology as craft whereby making is the main feature of craft. Presented as both the act of craft and the process of craft, Kim and Song found that teachers perceived making as a defining characteristic of a technological activity, in that, activities that did not contain making, were not considered technological in nature. A more general representation of what type of activity can be considered technological was presented by Waight (2014). In citing Ellul (1964), Waight emphasised that technological activity is a group of movements and actions that function to achieve a known end. A similarly more expansive consideration of the activities that may be considered technological in nature is presented as one of Xu et al.’s (2022) eight dimensions. Here the importance of the human element of the activity is again emphasised, and Mitcham’s (1994) depiction of a diverse range of human

behaviours—including crafting, inventing, designing, manufacturing, working, operating, maintaining, and designing—are all used to describe how technology manifests through human activity.

Technology as knowledge

Technology as knowledge was the most common aspect of NoT identified in the selected studies, with four explicit inclusions; technology as knowledge (Kim & Song, 2021; Xu et al., 2022), also as expertise (Waight, 2014) and technology as know-how (Fleming, 1992). From a broader perspective, Xu et al. cite Mitcham's (1994) development of Ryle's (1945) delineation between knowing-that and knowing-how. Mitcham proposed four categories of technological knowledge from least to most conceptual: sensorimotor skills or technemes, technical maxims, descriptive laws, and technological theories. Sensorimotor skills or technemes rely on knowing-how more than knowing-that. Xu et al. explain that the reason for this lies in how this knowledge is acquired, in that it can “not be acquired directly in propositions but by intuitive as well as trial and error learning or imitative apprenticeship to some master craftsman” (p. 2617). Technical maxims, descriptive laws and technological theories are regarded as more knowing-that than knowing-how. To take technical maxims as an example, Mitcham (1994) described these as being akin to rules of thumb (Bunge, 1967) or recipes (Gille, 1986), in that they “constitute an initial attempt to articulate successful making or using skills” (p. 193). Waight (2012) emphasised expertise as one of the key dimensions of NoT in giving examples of “how depth of knowledge and expertise determine engagement and critical evaluation of a technological system” (p. 2894). Further analysis of the intricacies between different categories of technical knowledge is beyond the scope of this review, but attention should again be drawn to Ryle's (1945) distinction between knowing-that and knowing-how. The distinction between propositional and procedural knowledge is important from the perspective of technological knowledge as despite being placed on a scale towards more conceptual knowledge, Mitcham maintains that technological knowledge is not exclusively categorised as knowing-that. This is particularly important given the following component of NoT.

Technology as volition

Initially presented by Mitcham (1994) in his analysis of the relationship between technology and engineering, technology as volition acknowledges that in becoming intertwined with human existence, technology is placed as the intermediary between humans and the world, ultimately leading to changes in humans' ways of doing and motivations for doing. Chen's (2011) continuum from instrumental to substantive theories of technology sought to explore the active role that technology plays within the development of human activity. Xu et al. (2022) adopt technology as volition to represent that technology goes beyond artifacts and includes activity and knowledge, and because of this, technologies assist in presenting and perceiving the nature of the world, and the way of human existence. Xu et al. provided the example of how human beings create spectacles, and that as a result of this, eyeglasses enhanced the power and efficiency of the user's eyes.

Technology as progression

Whereas technology as volition is explicit in the developmental orientation of technology, there were also instances where an instrumentalist future oriented NoT was proposed, namely, in depictions of technology as progression (Kim & Song, 2021; Waight, 2014). Most studies framed previous findings of predominantly instrumentalist views of technology, most often associated with technology as artifacts. Despite this, the continuously developing and changing NoT was highlighted, with traditional and emerging hardware and software associated with technologies used to exemplify this development. The important distinction between technology as volition and technology as progression stems from the autopoietic conception of technology inherent to a substantive theory of technology. Arthur (2009) notes the autopoietic perspective on technology tells us “that every novel technology is created from existing ones, and therefore that every technology stands upon a pyramid of others that made it possible in a succession that goes back to the earliest phenomena that humans captured” (p. 170). Technology as progression holds the relationship between humans and technology as interactive. Despite an interactive relationship between humans and technology, the relationship is one-directional, humans use technology to develop technology. Waight (2012) cites Volti’s (2009) representation of (technology as) progression as an “inherently dynamic and cumulative process” (p. 7).

History of technology

Closely related to the view of technology as progression is the retrospective conception of history of technology (Kim & Song, 2021; Xu et al., 2022). Whereas progression acknowledges the future oriented NoT, views on the history of technology situate existing technologies developed throughout the ages (and more recently) as an important factor in understanding NoT. Xu et al. (2022) note that the development of technology is closely related to the development of society, and its development speed is determined by external factors, personal creativity, and human needs. They compiled four test items to analyse teachers’ conceptions of NoT. These highlight the relationship between technology and civilization, technology and human development, and the influences of technology on society.

Relationship between technology and science

Yenilmez Turkoglu et al. (2022) did not include technology as knowledge, but instead focused on the epistemic relationship between science and technology. The specific statements which were used to investigate participants’ understanding of this relationship focused on delineating both concepts and describing how technology is different from science (Chaves & Moro, 2007). Further to this, a temporal perspective is taken whereby the co-evolution of technology and science is considered. Whether or not science is necessary for technological development, and how technology and science inform one another’s development are both considered (Aikenhead et al., 1989). Xu et al. (2022) also include the relationship between technology and science as one of their eight dimensions of NoT. In rejecting the technology as applied science mantra that pervaded much of early STS literature, Xu et al. noted that there are two key distinctions between science and technology from educational perspectives. First, they assert that the goal of science education is to develop students’ complete, scientific, and objective knowledge system, whereas the goal of Technology Education is not just for knowledge, but also for technological capabilities,

making and doing abilities. Second, it is noted that the outcomes of science education do not belong to a particular individual or group, whereas technology outcomes are context dependent and can belong to an individual or a group.

Technology as system

As humans have evolved, the nature of technologies that we create, adapt and use have also evolved. Modern technologies are highly complex and interconnected and, as a result of this, it is important to understand how different technologies interact with the world. One such approach is to view technology as system (Kim & Song, 2021) or technology as part of systems (Waight, 2014). Although the terminology of ‘system’ here may indicate an association with technology as artifact, and ideas about modularity and the subassemblies may come to the fore, the perspective taken is much more abstract. Historical patterns of technological change include a wide range of interactions, occurring at different levels and include individuals, organisations, and cultural values and practices (Pacey, 1983). Arthur (2009) uses the term ‘purposed systems’ to explore this and gives the example of the monetary system, importantly, not the papers and coins, but the monetary system holistically. Based on the principle that any category of scarce object can serve as a medium for exchange: gold, government-issued paper, or when these fail, cigarettes and nylons, Arthur notes that the system makes use of the phenomenon that we trust that the medium has value as long as we trust others also believe in this value, and importantly, that the trust will continue. The phenomenon here is behavioural in nature. Fleming (1992), again adopting from Kline, is more explicit in articulating technology as part of a sociotechnical system, shifting the emphasis from artifacts and the use of artifacts, and identifying that technology “must be much more than just the machinery and the people” (1985, p. 216). Further, while technology/ies are manufactured as part of sociotechnical systems, including but not limited to people; machinery; resources; processes; and legal, economic, political, and physical environments, a shift in emphasis from understanding the manufacture of technology/ies to a sociotechnical system of use changes the focus to understanding the purpose of Technology-as-phenomenon. Kline (1985) proposed that adopting this view of a sociotechnical system of use is essential to understanding the human implications of technology/ies.

Technology and society

It is notable that the role of technology in society (Xu et al., 2022), in its various forms, such as the impact of technology on the environment (Yenilmez Turkoglu et al., 2022) or the impact of technology on the economy (Yenilmez Turkoglu et al., 2022), was a common component in theoretical models of NoT. In drawing attention to the culturally situated nature of technological development, whether that is technological tools or artifacts, or a new process for the manufacture of silicon microprocessors, Waight (2014) emphasises the importance of culture and values as a core dimension of NoT.

On the one hand, compatible cultural values and lifestyles may facilitate the transmission of technologies into existing cultural contexts. An example of this would be the adoption of vaccinations, but in large proportions, indeed vaccine mandates presented an affirmative position by governments in many countries. In a similar vein, society may be opposed to or reject specific technologies. An example of this is highlighted by Sandler (2014), where genetically modified crops have been resisted in parts of Europe and Africa. In these examples, whether the technology/ies in question are viewed positively or negatively is

beside the point, emphasis should instead be drawn to the impact of technology on society (Yenilmez Turkoglu et al., 2022). On the other hand, some technologies are advocated by society. A poignant example of this is social demand for specific technologies through public funding, as is often the case for medical technologies. The technology-society relationship is viewed as bi-directional as, here, the focus is the impact of society on technology (Yenilmez Turkoglu et al., 2022). Whether viewed in a positive or negative light and there are abundant examples of both, technology/ies are implemented in and disseminated through society. Sometimes their purpose is to solve social problems (i.e., vaccines) and sometimes technologies create social problems (i.e., the impact of mining on the environment). Importantly, in no cases are technologies separate from a social context (Sandler, 2014). For Xu et al. (2022) the complex nature of technology and society and tensions inherent to the developmental NoT warranted an explicit focus on the indefinite implications of technology in their theoretical framework.

Technological ethics

Closely related to technology and society is the role of technological ethics. Xu et al. (2022) presented technology as a double-edged sword as one of their eight dimensions of NoT. It is noted that in the Chinese high school general technology curriculum, the dual characteristics and ethics of technology are emphasised in technology teaching to develop students' technological critical thinking and decision-making. Findings from Koc (2013) of the existence of metaphors of technology as power and technology as threat suggest the importance of adopting an ethical perspective on technology. Again, both positive and negative perspectives were taken by the preservice teachers in this study. For example, within the category of technology as power, the metaphor of technology as precious metals and finances was put forward. In holding technology as a valuable asset, Koc (2013) noted that technology provides actors with power so that they can remain standing and compete with others. Within the metaphor of technology as threat, however, the ethical implications are clearer. Whether metaphorised as 'virus' or 'cigarette', this category identified technology as something that poses a serious threat to human life (Koc, 2013). Technology was also likened to forms of addiction and dehumanisation. Despite the imminent and extensive affordances of technology/ies, a cursory development/use/adoption without consideration of the ethical implications would be naïve. To assist in such analysis, Xu et al. (2022) highlight De Vries's (2016) discussion of five contexts for discussing the ethics of technology: safety, environment, privacy, the military and human dignity.

Definition of technology

Perhaps most surprising from the list of 36 discrete components of NoT identified in the article's theoretical frameworks, just one presented the definition of technology as an explicit aspect of NoT (Table 3). In their Q-methodology study of science teachers' perceptions of NoT, Yenilmez Turkoglu et al. (2022) presented the definition of technology as one of six categories of statements holistically describing NoT. This category consisted of four statements that underpinned the definition of technology: technology consists of all the modifications humans have made in the natural environment for their purposes (Dugger, 2001); technology is a collection of ideas and techniques for designing and manufacturing things, for organising workers, business people and consumers, and for the progress of society (Aikenhead, Ryan, and Fleming, 1989); technology is a technique for doing things,

or a way of solving practical problems (Aikenhead, Ryan, and Fleming, 1989); and technology is a collection of techniques that include man-made artificial products, tools, and systems throughout the ages (Dumestre, 1999).

Nature of which t/technology?

While seven of the identified studies presented an explicit theorisation of NoT, the remaining studies adopted foundational approaches to analysing NoT. Through this analysis, a delineation was drawn between how specific *technologies* can manifest in the world, *Technology-as-phenomenon*, and *Technology Education* as a discipline. A clear demarcation between technologies, for example the existence of use of, reason for, or knowledge for specific identifiable *technology/ies*, and *Technology-as-phenomenon* proved useful due to the levels of abstraction through which NoT was described. For example, Koc (2013) conducted their study in the context of an educational technology course with pre-service teachers. This resulted in five conceptual categories describing preservice teachers' conceptions of educational technology as a specific *technology/ies*. With this approach, the specific *technology/ies* (i.e. educational technology) was the focus of the study, and in turn, the author drew implications for Technology more generally—*Technology-as-phenomenon*. In contrast, Xu et al. (2022) conducted a literature review in their development of a survey instrument. As a result of an expansive initial investigation, perspectives were garnered from Technology Education and the Philosophy of Technology, consequently, aspects of NoT here included those focused on specific *technology/ies* and *Technology-as-phenomenon*. Further, Xu et al. also drew on the body of literature concerning how to teach technology—*Technology Education*. In the following sections, evidence of these different levels of conceptualising t/Technology (Education) from the surveyed literature will be presented.

Manifestation of technology/ies

The different ways in which technology can manifest formed a significant part of the findings from individual studies. Most prominent here were findings of the dominance of conceptions of technology as artifact. In tandem with the theorisations of NoT outlined in the previous section, the use of the terms; artifact (Fleming, 1992; Sade & Coll, 2003; Waight, 2014), product (Bungum, 2006; Jarvis & Rennie, 1996; Rowell et al., 1999), devices (Chen, 2011), and tools (Kim & Song, 2021) all identified within the surveyed literature. It is important to note that this view is not presented as reductive, however, in the instance where a view of technology as artifact with a specific focus on modern (Chen, 2011; Fleming, 1992; Sade & Coll, 2003) or non-traditional artifacts (Sade & Coll, 2003), authors were more critical.

Despite all studies reporting on the prominence of teachers' conceiving technology as artifact as important, the process of *doing* technology/ies was less common, six studies found that teachers held the view of technology as activity. Tensions were identified in activities that were considered technological however, for example, McRobbie et al. (2000) equated technology as activity to "design practice" (p. 90) whereby the complex interrelationships between design practices, information, materials, and systems were presented as critical to preservice teacher development. Similarly broad conceptions of technological activity as problem-oriented design processes were found in multiple studies included in this review (Jarvis & Rennie, 1996; Jones & Carr, 1992). In contrast, few studies outlined

the *use of* technology as technological activity, with Jarvis and Rennie (1996) being a notable example. As will be discussed later, the centrality of making to defining technological activity was noted by participants in multiple studies as a defining characteristic of Technology Education.

Despite an explicit inclusion within four theorisations of NoT, teachers were not found to place such an emphasis on technology as knowledge, instead emphasising the activity centric NoT as a process and the development of artifacts. One notable exception here is where the concept of know-how (Fleming, 1992) or practical knowledge (Chikasanda et al., 2011; Jarvis & Rennie, 1996; Kim & Song, 2021) were used by teachers to articulate working in a technological way. In the study conducted by Chikasanda et al. (2011), “teachers associated technology education as training about how to use engineering materials, related tools and other gadgets such as computers and machines” (p. 605). The authors note that in this instance teachers again appeared to have a reductive view of technology as ‘modern’ artifacts. However, this was just one way in which technology as knowledge was represented in this study, as participants also identified that ‘workshop processes’ and knowledge of the ‘science of materials’ were also fundamental to NoT.

Conceptions of technology-as-phenomenon

Whereas the previous theme focused on how teachers conceived specific technologies, here a more holistic understanding of the nature of technology-as-phenomenon was observed. Within this theme, three subthemes were identified from the literature; (1) abiding nature of technological development; (2) symbiotic relationship with society; and (3) technology and ethics.

In bringing together the aspects of technology as artifact and technology as activity the abiding nature of technological development recognises that the study of technology/ies and how they have been developed is an important endeavour. Kim and Song (2021) and Xu et al. (2022) represented History of Technology in their theorisation of NoT for this reason. The process of “gaining knowledge of artifacts” (Sade & Coll, 2003, p. 97), and how they have been developed were held as important by participants in several studies (Chikasanda et al., 2011; Jarvis & Rennie, 1996; Jones & Carr, 1992; Kärkkäinen & Keinonen, 2010). Rennie (1987) reflected on their participant’s contrasting views on the history of technology, highlighting the dissonance between reductive conceptions of ‘modern’ technologies and the more expansive conception of a historical view of technology. For the teachers surveyed by Waight (2014), the historical and progressive aspects of technological development were implicit, as technology was more holistically conceived as representing advances in civilisation. In a sense, the abiding NoT reflected advances in society.

In alignment with a focus on the progress oriented NoT, the relationship between technology and society was prevalent in researcher’s theorisation of the construct, with six studies explicitly referencing the relationship between technology and society. Despite this focus, several authors noted limited findings on teachers’ reflection on the impact between technology and society (Rowell et al., 1999). These findings were particularly apparent in studies that were exploratory in nature (Davies & Rogers, 2000; Jarvis & Rennie, 1996; Jones & Carr, 1992; Mittell & Penny, 1997; Rowell et al., 1999), and it should be noted that where technology and society were used in designing research instruments, for example, the Q-Methodology study of Yenilmez et al. (2022), more nuanced findings of the relationship between technology and society were presented. Chen (2011) used the distinction between instrumentalist and substantive theories of technology to explore how and why

technology is developed and adopted. Despite the prominence of instrumentalist views of technology as artifacts for use, Yenilmez Turkoglu et al. (2022) suggest teachers' awareness of the symbiotic relationship between technology and society. While some teachers here were identified as holding an instrumentalist view and presented its "dependance on society" (Yenilmez Turkoglu et al., 2022, p. 2688), other teachers' were "tempered by technology-driven environmental and social issues" (Yenilmez Turkoglu et al., 2022, p. 2690).

Teachers were also found to have dualistic views on the implications of technology (Yenilmez Turkoglu et al., 2022). Within the context of educational technology, the metaphor analyses of Gök and Erdoğan (2010) and Koc (2013) both identified teachers' concerns over the potential negative implication which may arise from technological development. For Koc (2013), this finding suggested that participants held a narrow view of technology, as the technical and instrumental characteristics of the metaphor of technology as a threat described a formal understanding of technology as artifact. Despite many student teachers surveyed by Gök and Erdoğan (2010) acknowledging the affordances of technology, concerns over the 'harmful' and 'addictive' nature of some technology/ies prevailed.

Conceptions of technology education

The final theme which was identified in this analysis concerned studies where teachers' conception of the nature of technology Education was explored (Burns, 1992; Chikasanda et al., 2011; Jones & Carr, 1992; Lee et al., 2020; McRobbie et al., 2000; Rennie, 1987; Rowell et al., 1999; Sade & Coll, 2003). Two subthemes were identified in this analysis. First, the position of Technology Education relative to other curriculum learning areas, and how teachers construed the nature of technology Education. In place of explicit conventional disciplinary boundaries, technological activity was identified in studies as the core content of Technology Education (Bungum, 2006). Although an extensive review of the technological activities has been presented previously, it should be noted here that the focus appears to be predominantly on designing and making of physical objects (Mittell & Penny, 1997). While there are some contentions surrounding the types of technological activity that should be included, a differentiation between 'practical' Technology Education and conventional 'theoretical' subjects was also presented (Chikasanda et al., 2011; Jarvis & Rennie, 1996). While this differentiation was noted as being common, it should also be noted that the distinction was not very concise. Bungum highlighted how teachers' use of a practical-theoretical distinction is more related to the form of classroom organisation (project-based) as opposed to a body of knowledge distinction, with some teachers going so far as to represent the learning area as "useful rather than a book-subject" (Bungum, p. 41).

The second theme identified here was the impact of teachers' cultural frame of reference on their teaching and learning. Tensions surrounding the explicit content of Technology Education resulted in some teachers not considering Technology as a new learning area when introduced. For example, in the Norwegian context, Bungum (2006) noted that participating teachers do not, even in principle, consider technology as a new learning area that adds a new domain of content knowledge to the curriculum. The reason for this appears to stem from the project-oriented nature of technological practice and how conventional learning areas are traversed. A teacher in the study viewed Technology Education as merely a combination of elements already present in the Norwegian curriculum—"what makes the subject special is how the subject elements are put together in meaningful

contexts that facilitate practical project work” (p. 48). To describe the culturally situated nature of teachers’ understanding of NoT, Jones and Carr (1992) used the concept of teachers’ subcultures. In the context of Technology Education being introduced to the New Zealand curriculum in the early 1990s, teachers from multiple existing curricula learning areas were surveyed in discussing NoT. Through this analysis it was identified that the teachers’ specialism significantly influenced how teachers conceived NoT and how it should be taught in schools, for example, science teachers held the view of technology as applied science, social studies teachers emphasised the social aspects of technology “particularly in terms of awareness and the human aspects of technology” (Jones and Carr, p. 232). Where teachers did not have curriculum specialisms, for instance with the primary teachers surveyed by Jones and Carr, it was identified that subject subcultures did not exist, and in place of subjects shaping how NoT was conceived, teachers past experiences and personal interests influenced NoT being considered.

Discussion

This review revealed a significant challenge concerning the level of abstraction at which NoT is investigated and conceived. This level of abstraction adopted is of importance, as manifestations of Technology Education are largely dependent on what constitutes technology in a given context. To illustrate this, I will consider the example of educational technology, specifically the use of personal devices in the classroom.

As a specific identifiable technology, personal devices fall within the technology as artifact aspect of NoT in the findings presented. It is important to start here as a significant challenge of this review was in designing search syntaxes and defining inclusion and exclusion criteria to delineate between conceptions of technology and educational technology. This distinction is clearly drawn in Technology Education rhetoric (Doyle, 2024); however, the everyday use of technology does connote high technologies as discussed in the introduction. Given that several of the studies in this review were predicated on participants acknowledging that technology is more than modern devices such as computers (Symington, 1987), this suggests that an emphasis is being placed on developing a broader understanding of technology. In a similar way to the tensions identified in representations of technological knowledge and propositional knowledge (Waight, 2014; Xu et al., 2022), the recurring theme of goals for Technology Education being articulated in abstract ways (i.e., technological literacy, capability, technacy, etc.), suggests a move away from specific technology/ies as the foundation of Technology Education.

A similarly abstract view of technology as human activity was observed within this review, with an exhaustive array of actions being considered technological in nature. If we return to the example of personal device use, challenges begin to arise. In its most rudimentary form, personal devices may be used to facilitate the storing and sharing of information. If we consider alternative personal devices, such as textbooks or conventional stationery, the discussion around specific technology/ies shifts significantly. Similar to studies focused on ICT and education technologies in this review (Chen, 2011; Koc, 2013), the specific technology/ies merely provide the context for investigating technology, and they are not the focus of the studies. In a discussion of the epistemological basis of Technology Education, Morrison-Love (2016) proposed a transformative epistemology for the learning area and differentiated between Science and Mathematics, which are epistemically predicated on interpretation and proof respectively. Critically, Morrison-Love emphasises that

transformation does not necessarily refer directly to material change, instead refers to “the transformation of a tangible technological outcome from a conceptual perdurant ontological state into a tangible enduring ontological state” (p. 31). In essence, the practical nature of technology does not necessitate a hands-on activity for students, so long as an understanding of the practical nature remains a focus of learning. If this is applied to the use of personal devices in the classroom, it is difficult to reconcile how the use of technology may be represented as Technology Education.

Moving on from the use of a specific technology/ies, we can consider an investigation of Technology-as-phenomenon in a broader sense. There are many ways that this investigation could materialise in the classroom. From the aspects of NoT identified in this review, a historical perspective on personal device development, an ethical perspective on the sourcing of raw materials, or a societal perspective on the impact of personal devices may also be framed as a valid Technology Education activity. In returning to the previous point on what constitutes a technological artefact, it is notable that devices (in their manifest forms) will be central to any research, analysis and reporting within such activities.

This discussion becomes challenging when one considers the interplay between the aspects of NoT identified and asks the question; what constitutes Technology Education? Earlier I have highlighted how the singular use of technological artifacts does not constitute Technology Education. The practical nature of technology Education on the other hand was identified in many studies as a defining characteristic of the learning area. While a practical orientation was often juxtaposed with theoretical subjects (Bungum, 2006; Chikasanda et al., 2011; Jarvis & Rennie, 1996), it is notable that theoretical investigations of technological concepts were also held as important (technological ethics and technology and society for example). In considering the epistemological basis of Technology Education, the identification of teachers’ cultural frame as a defining characteristic was highlighted in several studies. The idiosyncrasies that a teacher brings to any classroom are widely recognised, in this review however, the idiosyncrasies and teachers’ personal subject construct were viewed as critical to teaching technology. Teachers were found to question the knowledge base of Technology Education in the instances where it was newly introduced (Bungum, 2006), and where teachers brought other subject specialisms with them to teach technology for the first time, these existing subject specialisms influenced how Technology Education is conceived (Jones & Carr, 1992). Although this may be perceived as a disadvantage, it was not reported in a negative sense. One notable exception to this was where studies were conducted at the most abstract level (i.e., Technology-as-phenomenon), as it was here that the demarcations between technology and other curriculum learning areas were most prominent. Represented by the relationship between science and technology aspect of NoT identified in the review, they suggest the need for a more comprehensive understanding of the epistemology of technology.

In considering the levels of abstraction in discussing technology, this analysis sheds light on the distinctions between specific technology/ies, Technology-as-phenomenon, and Technology Education and their implications for understanding NoT in educational research. These distinctions have significant theoretical and practical implications for the study of NoT.

Implications

It is unrealistic to expect students to become competent historians, sociologists, or philosophers of technology. Despite this, the breadth of aspects of NoT identified in this review

evidence a multitude of different ways in which Technology Education may be conceptualised. The aspects presented may be used by technology educators and students to consider the different perspectives on analysing specific technologies. As Pleasants et al. (2019) note, much of the prior work investigating students' NoT views have focused on how technology is defined, or the sorts of things that students categorise as technology. A similar trend was reflected in this review, and while it should be noted that articles were published in the late 1980s and throughout the 1990s, there is a need for more critical perspectives on what constitutes technology. While a focus on what teachers categorise as technology is important (e.g., Symington, 1987), neglecting to study conceptions of Technology-as-phenomenon (or as a learning area) facilitates the misrepresentations and characterisations of Technology found in education today. The delineation between manifestations of specific technology/ies or Technology-as-phenomenon may serve as a starting point for such investigations. In this vein, it is important to emphasise that this review focused on investigations of NoT independent of national contexts, but also, independent of technical contexts. Developing our understanding of the transferability of technological concepts between technical contexts is an important avenue for future research. While the distinction has been drawn clearly in previous research (e.g., Rossouw et al., 2011), there has been no empirical work in this area.

In making the distinction between manifestations of technology/ies and conceptions of Technology-as-phenomenon, this review also presents technology educators with a framework to discuss technologies and how they relate to broader technology concepts. This is perhaps most pertinent in the context of STEM Education narratives, where contentious representations of Technology have previously been problematised.

Finally, in the context of the somewhat tumultuous position of Technology Education on curricula internationally (Seery et al., 2019), the findings of this study also have significant implications for policy(makers). In a similar vein to the critique of abstract representations of technological literacy, technological capability and technacy as goals for Technology Education as a learning area, NoT is often conceived in abstract ways. Despite its position in curricular documentation, the contested theorisations presented here highlight the need for conceptual coherence. In moving forward, the findings also facilitate a representation of *Technology Education* as a learning area, while at the same time clarifying the place of specific technologies (for example, educational technologies) within broader education narratives.

Limitations

Like all systematic literature reviews, there are some limitations to this review that should be considered. First, this review is limited to English language research published in peer-reviewed journals. Despite the intention of ensuring that only high-quality research is included in the analysis, these decisions will limit the findings as quality work that has been completed in different languages and presented in different publication types (book chapters, theses, conference papers, technical reports etc.) is not considered for inclusion. This decision was based on the assumption that studies in peer-reviewed journal articles are viewed as being of the highest quality. Although this approach is common within systematic literature reviews (Wilson & Anagnostopoulos, 2021), it should be noted that the development of the findings presented herein through the inclusion of sources from different languages and publication types will only serve to further develop our understanding of teachers' conceptions of NoT.

Second, in the introduction, I have outlined how the origins of Technology Education are context dependent. In the same way that technology educators are recognised as having significant autonomy in the decisions around what and how to teach, curricula also contextualise Technology Education in different ways. This has been discussed previously in terms of the place technology holds in curriculum (Bell et al., 2017), and the relations between technology and other learning areas (McGarr & Lynch, 2017). Although the construct of focus within this study is at the highest level of abstraction, i.e., conceptions of NoT, there is the potential for variations in formal education curriculum titles to have been missed in the search. Although the referential backtracking undertaken has assisted in identifying this literature, it is possible that more remains.

Third, and related to the previous limitation, it is also worth noting that the national educational context did not form part of the analysis of this study. While the different contexts in which the studies were conducted are presented, the intention here is not to present a transnational comparison but rather explore the conceptions of NoT held by teachers and theorisations of NoT represented in empirical investigations of teachers' conceptions. Future research should consider the situated nature of teachers' conceptions in the context of national and/or curricular representations of NoT.

Finally, in comparison to other areas of educational research, Technology Education is a relatively new field of study. As a result, this review did not adopt a temporal component to identifying articles for inclusion. While this may be viewed as an advantage in that a more extensive literature basis was reviewed, it should also be noted that in certain contexts, there have been policy reforms since the studies were conducted. Wholly representing the extent of reforms in the countries surveyed goes beyond the remit of this review.

Conclusion

Technology Education is a relative newcomer to curricula internationally, mirroring this, the field of Technology Education research is recognised as being underdeveloped when compared to more established learning areas (Williams, 2011a, 2016). Seery et al. (2019) outlined the importance of evolving the research agenda in Technology Education and rationalised this in two different ways, to ensure that all technology students receive equitable provision, and because otherwise, the learning area will become increasingly at risk of being delegitimised due to a lack of clarity around its aims, functions, treatment, and benefit to students. In reviewing theorisations of NoT, this article highlights the need for conceptual coherence in future research. The identified and unacknowledged tensions between a focus on specific technology/ies and Technology-as-phenomenon evidence the complexity of Technology as a construct, but more importantly, it outlines the potential for very different manifestations of Technology Education. Despite NoT being included in several national curricula, the different theorisations identified represented epistemological tensions within the learning area and how Technology Education(s) manifests. It is envisioned that this systematic review may serve as a starting point for a shared understanding of NoT, and in turn, better establishing Technology Education as a learning area.

Notes

1. *Formal education* is the broad term used to describe the structured education system from primary (and in some cases preschool/kindergarten/nursery) school up to, but not

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- including university. In different contexts, terms such as pre-university, P-12 or K-12 may be used. In this study, practicing and pre-service teachers of formal education context were included.
2. The distinction between *technical* and *technology/ical* education is increasingly used within the field of Technology Education (Reinsfield & Williams, 2017) to delineate between subjects that traditionally focus on the mastery of material skills to develop products and Technology Education, which emphasises the need for students to bring together a range of knowledge, skills, and capabilities within a sociocultural context.
 3. Keirl (2015) uses the distinction between *Technology* (big T) to address the field of Technology-as-phenomenon while *technology/ies* (small t) refers to a singular or multiple identifiable and specific technologies. The same distinction is made in this paper whereby Technology Education is used as a generic term representing various manifestations of the learning area internationally. Although it should be noted that the variations in how Technology Education is formulated and represented are problematic in their own right, they fall outside the scope of this review.

Appendix 1

Characteristics of the studies included in this review (organized alphabetically).

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/uni- versity	Methodology and analytic approach
Bungum (2006)	Norway	Descriptive analysis of the 'Teknologi i Sko- len' (Technology in Schools [TiS] project)	$n = 14$ practicing teachers <i>Age:</i> not reported <i>Gender:</i> not reported <i>Experience:</i> not reported	<i>Type:</i> Pri- mary and Secondary schools <i>Location:</i> Norway	<i>Qualitative design</i> <i>Data collection:</i> Semi-structured interviews with teachers' and class- room observations <i>Data analytical</i> <i>approach:</i> (i) Within case analy- sis of individual teachers and (ii) cross-case analysis identifying similar- ities and differences between cases
Chen (2011)	U.S.A	To unveil the criti- cal philosophical stance teachers may have towards the integration of technology in the school curricu- lum	$n = 22$ preser- vice secondary mathematics teachers <i>Age:</i> 20–27 years <i>Gender:</i> 14 females, 8 males <i>Experience:</i> n/a	<i>Type:</i> Compre- hensive University <i>Location:</i> Midwest of the United States	<i>Qualitative design</i> <i>Data collection:</i> (i) Author/instructor classroom notes (ii) Teachers' statements on the philosophy of technology (iii) One-on-one semi-structured interviews with participants ($n = 5$) <i>Data analyti-</i> <i>cal approach:</i> Grounded Theory
Chikasanda et al. (2011)	Malawi	To develop an understanding of the influences impacting on the implementation of the techni- cal curriculum and how such influences affect teacher change towards a cur- riculum that enhances student technological literacy	$n = 6$ practis- ing technical teachers <i>Age:</i> not reported <i>Gender:</i> not reported <i>Experience:</i> 1–10 years teaching	<i>Type:</i> Secondary schools <i>Location:</i> Malawi	<i>Qualitative design</i> <i>Data collection:</i> Semi-structured interviews <i>Data analytical</i> <i>approach:</i> Inter- pretive analysis, grouping into themes

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/uni- versity	Methodology and analytic approach
Davies and Rogers (2000)	England	To investigate the influence of different factors on pre-service teachers' plan- ning for activities in the classroom incorporating both elements of science and D&T	<i>n</i> = 92 (<i>n</i> = 20, pilot) preser- vice primary teachers <i>Age</i> : not reported <i>Gender</i> : 88% female <i>Experience</i> : n/a	<i>Type</i> : Primary schools <i>Location</i> : England	<i>Mixed methods design</i> <i>Data collection</i> : Questionnaire at the beginning of the ITE course (adapted from the VOSTS instru- ment), school- based planning assignment, and post-practicum interviews (<i>n</i> = 10) <i>Data analytical approach</i> : Interpre- tive analysis of interview and assignment data. Descriptive analy- sis of all quantita- tive data
Fleming (1992)	Canada	To conduct an exploratory study of teachers' views on the nature of technology	<i>n</i> = 596 practis- ing K-12 teachers <i>Age</i> : Median age 38 years <i>Gender</i> : 58% female, 42% male <i>Experience</i> : Median experience 13 years	<i>Type</i> : K-12 schools <i>Location</i> : Saskatch- ewan, Canada	<i>Quantitative design</i> <i>Data collection</i> : Sur- vey (postal) send to a random sample of teachers. It comprised of three components (i) Teacher position: questions extracted from the VOSTS instrument (ii) Understanding of technology: research developed statements. Four subgroups each receiving four ques- tions (iii) Demographic information <i>Data analytical approach</i> : Qualita- tive element of open response questions is not reported. Pearson correlation coef- ficients were calculated to deter- mine relationships between VOSTS data and demo- graphic information

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/uni- versity	Methodology and analytic approach
Gök and Erdoğan (2010)	Turkey	To analyse stu- dents' percep- tions about technol- ogy through the metaphor analysis. In the study, technology is regarded as a general concept including all technological materials and equipment which pre-service teach- ers use in daily life and education settings	<i>n</i> = 487 pre-ser- vice teachers <i>Age</i> : not reported <i>Gender</i> : 73.3% female, 26.7% male <i>Experience</i> : n/a	<i>Type</i> : Uni- versity <i>Location</i> : Turkey	<i>Mixed-methods design</i> <i>Data collection</i> : Interview form/ questionnaire <i>Data analytic approach</i> : Metaphor analysis, described as con- tent analysis

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/uni- versity	Methodology and analytic approach
Jarvis and Rennie (1996)	England	In order to assist teachers to clarify their understanding of technology so that they can provide a more effective technology education in the primary school, the research reported by this paper set out to: (i) identify the factors that have influenced teachers' ideas; (ii) describe the variation and nature of teachers' understanding of technology; and (iii) examine teachers' experience of teaching technology as part of the primary curriculum	<i>n</i> = 142 practicing teachers <i>Age</i> : not reported <i>Gender</i> : not reported <i>Experience</i> : not reported	<i>Type</i> : Primary schools <i>Location</i> : England	<i>Mixed-methods design</i> <i>Data collection</i> : (i) Writing/drawing activity where respondents respond to a prompt "Please tell us what technology means to you by writing about it, or by drawing a picture. You might like to do both" (ii) Picture quiz. Respondents are asked to identify which of 28 pictures, presented on one page, have something to do with technology. The pictures, the selection of which is described by Rennie and Jarvis (1995), are intended to represent a wide range of possible ideas about technology (iii) Interviews (<i>n</i> = 13) Personal understandings of technology <i>Data analytic approach</i> : Inductive analysis using the framework presented by Jarvis and Rennie (1995)
Jones and Carr (1992)	New Zealand	To investigate teachers' perceptions of technology education	<i>n</i> = 30 practicing teachers (16 primary and 14 secondary) <i>Age</i> : not reported <i>Gender</i> : not reported <i>Experience</i> 2–30 years teaching experience	<i>Type</i> : Primary and Secondary schools <i>Location</i> : New Zealand	<i>Qualitative design</i> <i>Data collection</i> : Interviews <i>Data analytic approach</i> : not reported

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/uni- versity	Methodology and analytic approach
Kärk- käinen and Keinonen (2010)	Finland	The aim of this study was (1) to investigate primary school teacher students' perceptions of technology in cross curricular theme studies, and (2) to identify how thinking about technology changes while studying of the cross-cultural theme	<i>n</i> = 47 (beginning) and <i>n</i> = 36 (completed) <i>Age</i> : not reported <i>Gender</i> : not reported <i>Experience</i> : n/a	<i>Type</i> : University <i>Location</i> : Finland	<i>Qualitative design</i> <i>Data collection</i> : Mind maps, writings and student reports <i>Data analytic approach</i> : Content and discourse analysis

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/uni- versity	Methodology and analytic approach
Kim and Song (2021)	The Republic of Korea	To provide a detailed framework for the NOTE by investigating science and technology teachers' NOTE views, which can be used to support STEM education (RQ1) To what extent do science and technology teachers perceive 'technology' and 'engineering' as distinct entities? (RQ2) What are the elements of NOTE as perceived by teachers?	$n = 8$ (4 practising science teachers and 4 practising technology and domestic science teachers) Age: not reported Gender: 5 female, 3 male Experience: 2–16 years teaching experience	Type: Secondary schools Location: not reported	Qualitative design Data collection: Semi-structured interviews Data analytical approach: Phenomenography
Koc (2013)	Turkey	To investigate student teachers' conceptions about the nature of technology (i.e., beliefs of what technology is) through metaphor analysis (RQ1) What metaphorical images do student teachers use to conceptualize technology? What rationale do they provide to justify those images? (RQ2) In what ways, if any, do demographic variables influence student teachers' conceptions of technology?	$n = 237$ preservice technical teachers (45% Mechanical Education, 32% Construction Education, and 23% Electronic and Computer Education) Age: 18–26 years old (average 21 [SD 1.64]) Gender: 32% female, 68% male Experience: n/a	Type: College of Technical Education Location: Turkey	Qualitative design Data collection: Questionnaire Data analytical approach: Metaphor analysis

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/uni- versity	Methodology and analytic approach
Lee et al. (2020)	New Zealand	To investigate the influence of demographic and other factors on student attitudes and understandings of technology and Technology Education RQ1. What are the student teachers' views on technology? RQ1a. How important is technology to New Zealand as a country? RQ1b. What do you think the subject/learning area called technology is mostly about? RQ1c. What pedagogical notions do student teachers think are applicable to technology education, both technology and science education, or science education? RQ1d. What are student teachers' beliefs about technology? RQ2. How do student teachers' views on technology education differ by age-group? RQ3. How do student teachers' views on technology education differ by sector?	<i>n</i> = 906 ITE students (76.6% primary education, 21% ECE, and 3% secondary education) <i>Age</i> : 64.6% aged 17–24 years old <i>Gender</i> : 83.2% female <i>Experience</i> : n/a	<i>Type</i> : ITE provider (University) <i>Location</i> : New Zealand	<i>Quantitative design</i> <i>Data collection</i> : Survey <i>Data analytical approach</i> : Descriptive analysis of ordinal data (means and standard deviations) Cliff's delta (δ) effect sizes

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/uni- versity	Methodology and analytic approach
McRobbie et al. (2000)	Australia	<p>The objectives of the study were:</p> <ol style="list-style-type: none"> 1. To investigate the perceptions of design and technology that students bring to a preservice primary teacher education course; 2. To identify factors in a design and technology unit of study that may produce changes in preservice teachers' perceptions of design and technology; 3. To examine the implications of the study for preservice and in-service primary teacher education 	<p>$n = 130$ preservice primary education teachers</p> <p><i>Age:</i> not reported</p> <p><i>Gender:</i> approx. 3:1 (female:male)</p> <p><i>Experience:</i> n/a</p>	<p><i>Type:</i> University</p> <p><i>Location:</i> Australia</p>	<p><i>Mixed-methods design</i></p> <p><i>Data collection:</i></p> <p>Three instruments designed by Jarvis and Rennie (1994)</p> <p>(i) Writing/drawing activity (ii) Picture quiz, and (iii) Interviews ($n = 21$)</p> <p>Personal understandings of technology</p> <p>Following this, two focus groups of three preservice teachers each were purposefully selected for an in-depth analysis. Supported by field notes from the research team</p> <p><i>Data analytic approach:</i> Inductive analysis using the framework presented by Jarvis and Rennie (1995). Interviews described an interpretivist inquiry, following the guidelines of (Guba and Lincoln, 1989)</p>

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/uni- versity	Methodology and analytic approach
Mittell and Penny (1997)	England	To assess the extent to which tensions between the learning of knowledge and skills on one hand, and processes and understanding on the other were appreciated and understood, and influenced, practice and assessment in schools 1. Ascertain what heads of design and technology believe to be the nature and purposes of design and technology education	<i>n</i> = 61 Design and Technology Education head of department <i>Age</i> : not reported <i>Gender</i> : 93.4% male (<i>n</i> = 57) <i>Experience</i> : not reported	<i>Type</i> : Secondary schools <i>Location</i> : Hampshire, England	<i>Mixed-methods design</i> <i>Data collection</i> : Survey containing three components (i) statement of purpose for the subject, (ii) names of syllabuses and external examinations used, and (iii) a list of textbooks used <i>Data analytic approach</i> : Statements of purpose were analysed descriptively from a 4-point scale. Thematic analysis of open-ended questions on the statements of purpose Analytic approach for the syllabuses and external examinations was not presented Textbooks were categorised into 3 types based on a system developed by the authors
Rennie (1987)	Australia	To investigate the perceptions of technology held by senior science teachers	<i>n</i> = 94 science teachers <i>Age</i> : not reported <i>Gender</i> : not reported <i>Experience</i> : highly experienced but no data presented	<i>Type</i> : Secondary schools <i>Location</i> : Western Australia	<i>Qualitative design</i> <i>Data collection</i> : Allowed five minutes to write down their personal definition of technology <i>Data analytic approach</i> : not presented

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/uni- versity	Methodology and analytic approach
Rowell et al. (1999)	Canada	To investigate the ways in which technology is characterized by educators preparing to implement technological problem solving within the framework of a mandatory elementary science program	<i>n</i> = 11 practicing science teachers <i>Age</i> : not reported <i>Gender</i> : 11 female, 1 male <i>Experience</i> : 8–24 years	<i>Type</i> : Primary schools <i>Location</i> : Alberta, Canada	<i>Qualitative design</i> <i>Data collection</i> : Interviews <i>Data analytic approach</i> : Through repeated readings, data derived from interview transcripts have been analysed for the interests, assumptions and concerns of participants with respect to the nature of technology, technology-science relationships and teaching/learning technological problem solving
Sade and Coll (2003)	Solomon Island	To gain an understanding of primary teachers' perception of technology and technology education RQ1. What perceptions of technology and technology education are held by some Solomon Island primary teachers [and primary curriculum development officers]? RQ2. What factors might influence these Solomon Island primary teachers' [and curriculum development officers'] perceptions of technology and technology education?	<i>n</i> = 30 primary teachers <i>Age</i> : not reported <i>Gender</i> : 2/3 female <i>Experience</i> : 0–15 years	<i>Type</i> : Primary schools <i>Location</i> : Solomon Islands	<i>Qualitative design</i> <i>Data collection</i> : Semi-structured interviews supported by the <i>Picture Quiz</i> from Rennie and Jarvis (1995) <i>Data analytic approach</i> : not presented

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/uni- versity	Methodology and analytic approach
Stein et al. (2007)	Australia	Investigate how a professional development experience enabled teachers the extend their personal constructs of technology and technology education	<i>n</i> = 4 primary teachers <i>Age</i> : not reported <i>Gender</i> : not reported <i>Experience</i> : little prior experience	<i>Type</i> : Primary schools <i>Location</i> : Brisbane, Australia	<i>Mixed-methods design</i> <i>Data collection</i> : Variety of data sourced used (i) survey from Rennie and Jarvis (1994), (ii) teacher interviews, (iii) video recordings, (iv) artefacts, and (v) field notes <i>Data analytical approach</i> : Specific method of analysis not presented. However, a focus on teachers' understanding of technology, technology concepts and processes, and technology education is highlighted
Symington (1987)	Australia	To gather teachers' thinking about technology	<i>n</i> = 70 experienced primary teachers <i>Age</i> : not reported <i>Gender</i> : not reported <i>Experience</i> : not reported	<i>Type</i> : Primary schools <i>Location</i> : Australia	<i>Mixed-methods design</i> <i>Data collection</i> : In-person questionnaire <i>Data analytical approach</i> : Descriptive analysis of quantitative survey responses. Open ended questions (method not reported)

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/uni- versity	Methodology and analytic approach
Waight (2014)	U.S.A	To examine high school science teachers' conceptions of technology and by extension how these conceptions reflected dimensions of NOT. In-depth interviews guided by video elicitations explored the following research questions: (RQ1) How do high school science teachers define technology? (RQ2) What are high school science teachers' reflections of technologies (e.g., educational, social, and political) in the context of video scenarios representing a range of technologies and associated activities? Collectively, in what ways did teachers' conceptions reflect understandings of, or lack of, of NOT?"	$n = 30$ high school science teachers, living environment (19), earth science (11), chemistry (10), environmental science (9), and physics (7) <i>Age:</i> not reported <i>Gender:</i> 15 female, 15 male <i>Experience:</i> less than 10 years ($n = 17$), 11–20 years ($n = 9$), 21–30 years ($n = 3$), and 31–40 years ($n = 1$)	<i>Type:</i> Urban, suburban and rural high schools <i>Location:</i> Northeastern city, United States	<i>Qualitative design</i> <i>Data collection:</i> Interviews (part video prompted) <i>Data analytical approach:</i> Interpretive analysis and coding by two readers (inter-rater agreement established at 94%)

Author(s) (year)	Country	Study aims and research questions (if presented)	Participants	Type and location of school/university	Methodology and analytic approach
Xu et al. (2022)	China	(1) To define the conceptions of NOT from the literature review (2) To construct the theoretical framework of technology teachers' understandings of NOT according to Step one (3) To develop and validate an instrument for assessing technology teachers' understandings of NOT	<i>n</i> = 835 practising technology teachers <i>Age</i> : not reported <i>Gender</i> : not reported <i>Experience</i> : not reported	<i>Type</i> : High school general technology teachers <i>Location</i> : Mainland China	<i>Mixed-methods design</i> <i>Data collection</i> : Online survey <i>Data analytical approach</i> : Instrument development including theoretical analysis of the Philosophy of Technology Literature, Expert (<i>n</i> = 8) Panel content validation, and CFA with the stratified random sample (<i>n</i> = 835)
Yenilmez Turkoglu et al. (2022)	Turkey	To investigate a sample of science teachers' perspectives of technology using the Q methodology approach (RQ1) What are the different perspectives of science teachers concerning the nature of technology? (RQ2) What are the descriptions associated with the perspectives that science teachers posit about the nature of technology?	<i>n</i> = 17 practising science teachers <i>Age</i> : not reported <i>Gender</i> : 11 female, 6 male <i>Experience</i> : one year (<i>n</i> = 2), two years (<i>n</i> = 2), three years (<i>n</i> = 1), four years (<i>n</i> = 1), five years (<i>n</i> = 1), seven years (<i>n</i> = 1), eight years (<i>n</i> = 4), ten years (<i>n</i> = 1), thirteen years (<i>n</i> = 2), twenty one years (<i>n</i> = 1), and twenty six years (<i>n</i> = 1)	<i>Type</i> : Secondary teachers <i>Location</i> : Turkey	<i>Mixed-methods design</i> <i>Data collection</i> : Q-sort methodology consisting of 36 statements followed by a qualitative structured interview <i>Data analytical approach</i> : Q-sorts (<i>n</i> = 17) were analysed using PQ Method 2.35 software forming an inter-correlation matrix. Principal component analysis and varimax rotation were then made to maximise the variance explained on the minimum number of factors possible The analytical approach used to analyse qualitative data (i.e., interviews) is not reported

VOSTS views on science-technology-society, RQ research question, NOTE nature of technology and engineering, STEM science, technology, engineering, and mathematics, SD standard deviation, ITE initial teacher education, ECE early childhood education, CFA confirmatory factor analysis, NOT nature of technology.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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